APPENDIX C
BASIC PRESTRESSING GUIDELINES

Prestressed concrete is created by compressing a concrete unit (i.e., beam, pile, deck panel) with 7-wire strand (tendon). The individual strands within a unit or series of units are tensioned to the calculated stress required and held in place at the ends of the prestressing beds.

The reinforcing steel and other design inserts are tied in place and concrete is placed and allowed to cure until it meets the required compressive strength. The tendons are then released transferring the stress into the concrete. This creates compressive stresses in the unit that will resist the final stresses a member will be subjected to in the structure.

To ensure that the proper stress has been achieved, elongation of each strand will be measured after tensioning. During the tensioning process gauge readings will be monitored to ensure that over tensioning does not occur.

The tensioning of straight strand may be achieved by jacking from one end. This method may not be sufficient to ensure uniform stress distribution in the draped strand due to friction caused at the deflection points. To ensure proper stress distribution, the fabricator may desire to jack from both ends and/or harp. The fabricator Quality Control Manual will describe an approved method(s).

The maximum jacking stress in prestressing strand is 80% of the specified minimum ultimate tensile strength (0.80 f'_s), including allowances for seating losses and temperature differences.

Normally, there are losses in length of strand elongation as the strands are pulled to the required tension. These losses may come from slippage of the strand in gripping devices such as live and dead end chucks or splice chucks. The slippage is small, normally under 13.0 mm (½ in.), and is the "seating" of the strand within the chuck which allows the device to hold the strand. Also, some fabrication lines have abutments on the end of the lines, which withstand the forces imposed by the tensioned strands. There may be some rotation of these abutments toward the center of the casting bed. This will also cause some loss in the length of strand elongation. Similarly, the casting bed itself may shorten in compression, as the strand, connected to these "self-stressing" beds, is tensioned. All of these losses in elongation length must be determined by the fabricator and documented in the Quality Control Manual for the plant. These losses in line setup and corrections for temperature in accord with Article 2407.06 will be included in the tensioning calculations prepared by the fabricator for each line setup.

STANDARD

The formula to determine the elongation needed to produce the required stress is:

$$\frac{P \times L}{A \times E^*}$$

P = required load (stress) applied to strand
L = length of strand between anchorages
A = area of strand (from strand supplier load elongation curve)
E = modulus of elasticity (load elongation curve)

* An established average product of modulus of elasticity and the area may be used if the product of the actual modulus and the actual area is within 2.5% of an established value.

EXAMPLE

This example is based on a plant that employs harping the draped strands to achieve the final strand position and elongation. The required harping distance and elongation have been predetermined by the fabricator.

Unit Type: LXA-55 (three units)
Number of Strands: 22 (6 draped and 16 straight) standard sheet
Total Initial Prestress: 681.2 kips

Strand Characteristics: (Load Elongation Curve)

Type: ½ in. 270 k Lo-Lax
Actual standard area: 0.154 sq. in.
Modulus of elasticity: 28,800,000 psi (28,000 ksi)
Established product of average modulus of elasticity and average area: 4,406,400 psi (4,406.4 ksi)
Actual modulus of elasticity times actual area = 4,435,200 lbs. (4,435.2 kips)

Plant Setup Information:

Length of draped cables before harping: 2725.51 in. (227.13 ft.)
Length of straight cables: 2730.0 in. (227.5 ft.)
Predetermined elongation due to harping: 2.96 in.
Live end slippage (chuck seating): 0.65 in.
Initial tensioning (to remove slack): 1000 lb. pull
Temperature at time of tensioning: 60°F

Calculations:

Determine the required stress in each cable:

$$\frac{681.2\,\text{kips}\,(681{,}200)}{22\,(\text{no. of cables})} = 30{,}964\,\text{lbs.}$$

Acceptable range of established product (A x E) = .975 (4,406,400) to 1.025 (4,406,400) = 4,296,240 to 4,516,560

4,435,200 is within the range ∴ use the established value

Determine the distance one inch of cable must be elongated:

$$\frac{P \times L}{A \times E} = \frac{30{,}964 \text{ lbs.} \times 1 \text{ inch}}{4{,}406{,}400} = \frac{30{,}964}{4{,}406{,}400} = 0.00703 \text{ in./in.}$$

Determine elongation needed for draped strands:

2725.51 (cable length) x 0.00703 (in./in.) = 19.16 in.
Loss from chuck seating = 0.65 in.
Initial tensioning elongation: $\frac{1000 \times 2725.51 \times .00703}{30{,}964} = 0.62 \text{ in.}$

Elongation due to harping: 2.96 in.

Required elongation to develop needed stress: 19.16 in. + 0.65 in. - 0.62 in. - 2.96 in. = 16.24 in.
at 70°F adjusted by 1.0% for each 10°F deviation from 70°F = 16.24 in.
x .01 = 0.162; 16.24 + 0.162 = 16.402 at 60°F.

Determine the elongation needed for straight strands:
2730.0 in. (cable length) x 0.00703 (in./in.) = 19.19 in.
Loss from chuck slippage = 0.65 in.
Initial pull elongation = 0.62 in.
19.19 + 0.65 - 0.62 = 19.22 @ 70°F
19.22 x .01 (1.0%) = 0.192; 19.22 + 0.192 = 19.41 in. @ 60°F

METRIC

The formula to determine the elongation needed to produce the required stress is:

$\frac{P \times L}{A \times E*}$

P = required load (stress) applied to strand
L = length of strand between anchorages
A = area of strand (from strand supplier load elongation curve)
E = modulus of elasticity (load elongation curve)

* An established average product of modulus of elasticity and the area may be used if the product of the actual modulus and the actual area is within 2.5% of an established value.

EXAMPLE

This example is based on a plant that employs harping the draped strands to achieve the final strand position and elongation. The fabricator has predetermined the required harping distance and elongation.

Unit Type: B17M (three units)
Number of Strands: 22 (6 draped and 16 straight) standard sheet
Total Initial Prestress: 3030 kN

Strand Characteristics: (Load Elongation Curve)

Type: 13 mm 1201 kN Lo-Lax
Actual standard area: 99.4 mm^2
Modulus of elasticity: 198,600 MPa
Established product of average modulus of elasticity and average area: 19,600 kN
Actual modulus of elasticity times actual area = 19,730 kN

Plant Setup Information:

Length of draped cables before harping: 69,228 mm (69.23 M)
Length of straight cables: 69,342 mm (69.34 M)
Predetermined elongation due to harping: 75.184 mm
Live end slippage (chuck seating): 16.51 mm
Initial tensioning (to remove slack): 4,448.22 N Pull
Temperature at time of tensioning: 16°C

Calculations:

Determine the required stress in each cable:

$$\frac{3030\,\text{kN}}{22\,(\text{no. of cables})} = 137.73\,\text{kN}$$

Acceptable range of established product (A x E) = .975 (19,600 kN) to 1.025 (19,600 kN) = 19,110 kN to 20,090 kN

19730 kN is within the range ∴ use the established value

Determine the distance one mm of cable must be elongated:

$$\frac{P \times L}{A \times E} = \frac{137.733\,\text{kN} \times 1\text{mm}}{19{,}600\,\text{kN}} = 0.00703\,\text{mm/mm}$$

Determine elongation needed for draped strands:

69,228 mm (cable length) x 0.00703 (mm/mm) = 486.68 mm
Loss from chuck seating = 16.51 mm

Initial tensioning elongation: $\frac{4448.22 \text{ x } 69228 \text{ x } .00703}{137.733} = 15.72 \text{ mm}$

Elongation due to harping: 75.184.mm

Required elongation to develop needed stress: 486.68 + 16.51-15.72-75.18 = 412.29 mm at 21°C adjusted by 1.0% for each 5.6°C deviation from 21°C =
412.29 mm x .01 = 4.12
412.29 + 4.12 = 416.41 at 15.4°C.

Determine the elongation needed for straight strands:
69,342 (cable length) x 0.00703 (mm/mm) = 487.47 mm
Loss from chuck slippage = 16.51 mm
Initial pull elongation = 15.72 mm
487.47 + 16.51 - 15.72 = 488.26 @ 21°C
488.26 x .01 = 4.88
487.47 + 4.88 = 492.35 @ 15.4°C